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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE

LOS ANGELES MEETING

AT

THE UNIVERSITY OF CALIFORNIA AT LOS ANGELES

Los Angeles, California

January 2–3, 1948

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JANUARY 2, 1948 Vol. 23, No. 1

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

LOS ANGELES MEETING, JANUARY 2–3, 1948

THE 283rd meeting of the American Physical Society will be held at the University of California, Los Angeles, on Friday and Saturday, January 2 and 3, 1948. Because of the unusually large number of contributed papers, it will be necessary to have five sessions. The two sessions of Friday, starting at 9:30 A.M. and 2:00 P.M., respectively, and the morning session on Saturday, starting at 9:30 A.M., will be held in Room 19 Chemistry and will compose both invited and contributed papers. Contributed papers only will compose the two simultaneous sessions starting at 2:00 P.M. on Saturday, in Room 19 Chemistry and Room 29 Physics-Biology.

Invited papers will be given by C. T. Elvey and W. W. Hansen at the beginning of the Friday morning session, by S. J. Barnett on Friday afternoon at 2:00 P.M., and by G. T. Seaborg and J. G. Hamilton at the beginning of the Saturday morning session, all in Room 19 Chemistry. Luncheon arrangements will be announced at the meeting.

A list of hotels and motels within reasonable distance from the University has been sent to most of the organizations and institutions which are likely to have representatives at this meeting. The Local Secretary will be happy to attempt to obtain accomodations for those who have not received the list.

Prospective meetings of the Society are planned as follows: New York (1947 Annual Meeting), January 29–31, 1948; Washington, D. C., April 29, 30, May 1, 1948.

GENERAL RULES RELATING TO PAPERS

It is stipulated in the By-Laws of the Society that no contributed paper may be accepted for presentation at any meeting of the Society unless the title and an abstract of the paper are delivered to the office of the Society not later than the closing date stated in the printed call for the meeting.

The time allowed for the oral presentation of a contributed paper is ten minutes at most.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited to the one first named in its title.) For each paper on this programme the Secretary indicates a session at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in shortened form, or may read it by title.

Titles and abstracts of the papers to be presented are given in the following pages. Proofs of these abstracts have not been submitted to the authors. After submission of proof the abstracts will be published in an early number of "The Physical Review."

J. KAPLAN
Local Secretary for the Pacific Coast
University of California
Los Angeles, California

DEC 16 1947

PROGRAMME

FRIDAY MORNING AT 9:30

Room 19, Chemistry Building

(J. W. ELLIS presiding)

Invited Papers

A1. Physics of the Upper Atmosphere. C. I. ELVEY, *U. S. Naval Ordnance Test Station, Inyokern.* (30 min.)

A2. Linear Electron Accelerators. W. W. HANSEN, *Stanford University.* (45 min.)

Contributed Papers

A3. Collisions of the Second Kind. JOSEPH KAPLAN, *University of California, Los Angeles.*—Ta-You Wu[1] has listed thirty-two possible excitation processes in the upper atmosphere and among these were eighteen collisions of the second kind in which the energy of electronic excitation of one particle is transferred into the energy of electronic and vibrational excitation of a molecule. A typical example is $N_2(A^3\Sigma)+O(^1S)\rightarrow O(^1D)+N_2(B^3\Pi)$, the latter in the fifth vibrational level. The resonance in this case is very close and the spin rule is obeyed, hence Wu states that the cross section for this process may be of the same order as the gas kinetic values. The Franck-Condon principle is obeyed.[2] The writer has studied this and similar collisions involving metastable nitrogen molecules and metastable atoms of oxygen and nitrogen. The results suggest that such collisions have much smaller cross sections than have hitherto been assumed. These results are consistent with new ideas concerning the nature of excitation processes in the auroral afterglow,[3] and point the way to new experiments designed to make careful determinations of collision cross sections.

[1] Ta-You Wu, Proc. Ind. Acad. Sci. **18A**, 47 (1943).
[2] R. E. Meyerott, Phys. Rev. **71**, 553 (1947).
[3] J. Kaplan, Phys. Rev. (to be published).

A4. Anomalous Dispersion and Absorption of Ultra-Short Electromagnetic Waves in some Fatty Acids. G. POTAPENKO AND D. WHEELER, *California Institute of Technology.*—The dielectric constant and the coefficient of absorption of electric waves 25 cm long has been measured in dilute solutions of formic, acetic, propionic, and butyric acids in dioxane. Second Drude's method has been used, with Slatis' correction for the eddy currents in the condenser leads. A new method has been developed for computing the effective volume of the rotating portion of the molecule from the data obtained. The computed volumes are found to be proportional to the molecular volume. This shows that the anomalous dispersion and absorption of ultra-high frequency waves in acids investigated is due to the orientation of the entire molecule as a unit. In this respect fatty acids differ from simple alcohols in which, as it has been shown earlier,[1] the anomalous dispersion and absorption is due to the orientation of the dipole-bearing group (hydroxil), which rotates in the high frequency field independently of the rest of the molecule. This difference between the acids and the alcohols is attributed to the difference in the interatomic forces which in acids hinder greatly the rotation of carboxyl group.

[1] E. Keutner and G. Potapenko, Phys. Zeits. **38**, 635 (1937); **40**, 100 (1939).

A5. Propagation Characteristics in a Coaxial Structure with Two Dielectrics. ALFREDO BAÑOS, JR., H. GRUEN, AND DAVID S. SAXON, *University of California.*—The propagation characteristics for circularly symmetric TM-modes in a coaxial structure with two dielectrics offer many points of interest. For a given mode, the pertinent parameters are the ratio of the dielectric constants of the two media involved, the ratio of the two radii, and the operating frequency, expressed, say, in terms of the cut-off frequency for the *empty* guide. Among the results of special interest are the facts that, as already pointed out by Frankel,[1] the phase velocity for a given propagating mode may lie between the phase velocities corresponding to each of the two unbounded dielectrics and that, by proper choice of parameters, it is always possible to obtain a phase velocity of a pre-assigned value higher, of course, than the lower of the two velocities for the unbounded media. This suggests the possibility of using such structures in linear accelerators. Some results of an extensive computational program are presented in the form of families of curves showing the dependence of the propagation constant and of the phase velocity on the parameters of interest. Some discussion of field distributions is also given.

[1] Sidney Frankel, J. App. Phys. **18**, 650 (1947).

A6. On the Hyperfine Structure of Gallium. G. E. BECKER* AND P. KUSCH, *Columbia University.*—The hyperfine structures of the ground $^2P_{1/2}$ and the metastable $^2P_{3/2}$ states of Ga^{69} and Ga^{71} have been determined by the atomic beam magnetic resonance method. The h.f.s. levels for an atom whose nucleus has a magnetic dipole, electric quadrupole, and magnetic octupole moment are given by the formula $W=aC/2+bC(C+1)+c(C^3+4C^2+4C/5)$, where $C=F(F+1)-I(I+1)-J(J+1)$. For the metastable

state of gallium, with $I=J=\frac{3}{2}$, there are four levels at zero external magnetic field, corresponding to $F=3$, 2, 1, and 0. The determination of the separations of these levels permits the calculation of the constants a, b, and c in the equation above. It was found that only the first two terms are needed to explain the hyperfine splitting of each Ga isotope, within the precision of these measurements. An upper limit for the value of c is $3\cdot10^{-9}$ cm^{-1}. Other results are: $a_{71}=8.0868$ and $a_{69}=6.3644\cdot10^{-3}$ cm^{-1}; $b_{71}=5.4759$ and $b_{69}=8.6894\cdot10^{-5}$ cm^{-1}; $Q_{71}=.117$ and $Q_{69}=.186\cdot10^{-24}$ cm^2. The $\Delta\nu$ of the normal state of each isotope has been determined by the use of transitions in which $\Delta m_I=\pm1$, $\Delta m_J=0$ in the Paschen-Back region. $\Delta\nu_{71}=.113488$ and $\Delta\nu_{69}=.089319$ cm^{-1}. The ratio $(\Delta\nu_{71}/\Delta\nu_{69})=1.27059$ is in good agreement with $(a_{71}/a_{69})=1.27063$.

* Now at Stanford University.

A7. On the Absorption Spectrum of Active Nitrogen. R. EDWIN WORLEY,* *University of California.*—The problem of absorption through active nitrogen has been reattacked, using a 13-meter path,[1] at pressures of a few millimeters. An observation of the O_2 "atmospheric" bands (magnetic dipole, intercombination) showed that *allowed* transitions should be detected for a concentration of 10^{10} molecules/cm^3 in the initial vibrational level. Absence of the O−O band of N_2^+ indicates that the (unexcited) ion is not a primary carrier of the energy, as was proposed by Mitra.[2] Failure to observe first positive bands (N_2, $B^3\Pi\rightarrow A^3\Sigma$)—either from $v''=0$ or from v'' levels favored by the afterglow—is evidently due in part to the small fraction of molecules that reach $A^3\Sigma$ *via* the afterglow.[3] In addition, traces of mercury vapor probably reduced the life of this metastable state. Results obtained by Rayleigh[3] suggest that certain states of the neutral molecule, lying above the first ionization limit and apparently metastable,[4] may play a role in activation. A test of this possibility is planned.

* Now at the University of Southern California.
[1] H. D. Smith and J. K. Marshall, J. Opt. Soc. Am. **30**, 338 (1940).
[2] S. K. Mitra, "Active Nitrogen—A New Theory," Indian Press Ltd., Calcutta (1945).
[3] Lord Rayleigh, Proc. Roy. Soc. **151**, 567 (1935); **176**, 1, 16 (1940); **180**, 123, 140 (1942).
[4] R. E. Worley, Phys. Rev. **64**, p. 215 (1943).

A8. Parallel-Plate Counters and the Measurement of Very Small Time Intervals. J. W. KEUFFEL, *California Institute of Technology.*—The counter characteristics of a discharge tube using plane parallel electrodes are being investigated, especially with regard to the short time-lags ($\sim10^{-9}$ sec.) which have been reported in the breakdown of overvolted spark gaps.[1] A parallel-plate counter using copper plates 35 cm^2 in area and spaced 2.4 mm was found to have the following characteristics, when filled with $\frac{1}{2}$ atm. of argon and 6 mm xylene: threshhold 1500 volts; plateau 1500 volts, with a slope of 4 percent/100 volts; pulse rise time, $\sim5.10^{-9}$ sec. A multivibrator quenching circuit, with a quench time of .05 sec., was employed. The rise-time was measured by means of a timing circuit similar to that described by Neddermeyer *et al.*[2] Construction of a multi-detector model of the timing circuit, which should permit the measurement of very small time intervals between ionizing events, as well as an estimate of the uncertainty in reaction time of the counters, is now under way.

[1] L. B. Loeb, *Fundamental Processes of Electrical Discharge in Gases* (Wiley and Sons, Inc., New York, 1939), p. 447ff.
[2] Neddermeyer, Althaus, Allison, and Schatz, Rev. Sci. Inst. **18**, 488 (1947).

FRIDAY AFTERNOON AT 2:00

Room 19, Chemistry Building

(E. C. WATSON presiding)

Invited Paper

B1. Magnetization and Rotation. S. J. BARNETT, *California Institute of Technology and University of California, Los Angeles.* (30 min.)

B2. The Gravitational, Electromagnetic, and Vector Meson Fields and the Similarity Geometry. BANESH HOFFMANN,* *Institute for Advanced Study, Princeton* (by title).—In the general conformal geometry of space-time, the null geodesics are invariant. There is a special case, which may be called the similarity geometry, in which all geodesics are invariant. Let $S_{\sigma\tau}$ be a symmetric tensor, of index $2N$, belonging to this similarity geometry, and let S and Z be respectively the determinant and the curvature scalar formed from it. Then,[1] since $Z(S)^{\frac{1}{2}}/(S_{00})^2$ is gauge invariant, consider the four-dimensional variational principle

$$\delta\int\{Z(S)^{\frac{1}{2}}/(S_{00})^2\}dx^1dx^2dx^3dx^4=0. \qquad (1)$$

If $S_{\sigma\tau}$ is subject to the invariant restrictions $S_{05}=0$, S_{55}/S_{00} independent of the coordinates, (1) yields the general relativity field equations for the gravitational, electromagnetic, and vector meson fields. Removing the restrictions on $S_{\sigma\tau}$ introduces two additional scalar fields which are under investigation.

* On leave from Queens College.
[1] Compare Hoffman, Phys. Rev. **72**, 458 (1947).

B3. Dust Electrostatics. JAMES W. HANSEN, *University of California.* (Introduced by Leonard B. Loeb.)—The work reported on at the June 1947 Stanford meetings has been continued. Varying the length of the dusting tower has shown that the charge-size relationship and the particle-size distribution change markedly after the dust leaves the duster. Considerable evidence is available to show that this change is due primarily to aggregate formation. Details of such changes in distribution which it is impossible to summarize in this abstract will be presented.

B4. Water Drop Corona at Reduced Pressures. W. N. ENGLISH, *University of California.* (Introduced by Leonard B. Loeb.)—An extension of the experiments[1] with a water drop point, in a point to plane corona gap, to the pressure range 205 to 760 mm Hg has clarified the results obtained at atmospheric pressure, and furnished a striking proof of the dependence of negative point corona on secondary electron emission from the cathode. It appears that normal negative corona cannot occur on a water point, owing to the extremely low secondary electron emission coefficient. The luminosity observed with a negative drop point may then be attributed to streamer discharge from the positive end of the receding spray droplets in the high field region, as observed by Macky[2] with larger drops in a uniform field. The effect will also take place with a positive point, the streamers occurring from the lower positive ends of the droplets. The complex oscilloscope pulses obtained on positive and negative polarity, and the other features of the corona, can be convincingly explained with the aid of this mechanism.

[1] W. N. English, Phys. Rev. **72**, 741(A) (1947).
[2] W. A. Macky, Proc. Roy. Soc. **133**, 565 (1931).

B5. Positive and Negative Point to Plane Corona. L. B. LOEB AND W. N. ENGLISH, *University of California, Berkeley.*—A comparison of positive and negative metal point to plane corona in air has been made in the pressure range 205 to 760 mm Hg. Current-voltage characteristics reveal that the onsets, Vg, are almost identical and that the curve for negative point lies always above that for positive point, doubtless because of the more efficient generation of space charge in the latter. Reasonable negative point characteristics were most difficult to obtain, and the dependence of this corona on surface properties of the point is evident. A study of the intermittent regime onset, Vg, as a function of pressure shows very nearly the expected linear relationship for a positive point, but a decided curvature for the negative. This means a small difference in positive and negative onset near 500 mm Hg pressure, which can however be readily accounted for within the mechanism suggested by Loeb,[1] when the effect of absorbed gas films on the secondary electron emission of the point is considered. A preliminary experiment with non-metallic points of FeS and CuO has yielded an unexpected difference in the onsets Vg^+ and Vg^- at atmospheric pressure.

[1] L. B. Loeb, Phys. Rev. **71**, 712 (1947).

B6. Low Energy Mesotrons at High Altitudes.* DONALD C. MOORE AND ROBERT B. BRODE, *University of California.*—A series of cloud-chamber photographs have been taken in the flights of a B-29 at 30,050 feet and at 18,300 feet. To observe the frequency of occurrence of the various components of the cosmic radiation the cloud chamber was operated at random. The presence of six horizontal metal plates in the cloud chamber enabled one to distinguish between slow mesotrons, slow protons, electrons, and fast penetrating particles. Both the diffuse tracks due to pre-expansion particles and the sharp tracks due to fast expansion particles have been analyzed. The necessary corrections for chamber sensitive time, gas pressure in the chamber, and solid data angle of observation have been applied to these data. These measurements give the number of mesotrons with a range between 0.7 cm and 3.3 cm of lead and those with ranges greater than 3.3 cm of lead per square cm, per minute, per unit solid angle at the zenith. Combining the data obtained in these flights with data of other observers for higher energy mesotrons, energy spectra are obtained from 28 Mev to 520 Mev. The 30,050 feet energy spectrum has a maximum of 14 mesotrons per square cm, per minute, per unit solid angle at the zenith per Bev energy interval at 0.2 Bev. At 0.4 Bev the intensity is about 3. For the 18,300 feet spectrum the maximum is also at 0.2 Bev and has a value of 14. At 0.4 Bev the intensity is about 1. The 18,300 feet spectrum cannot be accounted for by higher energy mesotrons coming from upper layers of the atmosphere, but rather, represents more nearly the creation spectrum of mesotrons. The absorption coefficient of a primary radiation that would produce the observed altitude variation of the slow mesotrons is calculated to be about 130 grams per square cm.

* The research described in this abstract was supported in part by the Office of Naval Research.

B7. The Mass of Cosmic Ray Mesotrons.* J. G. RETALLACK AND R. B. BRODE, *University of California.*—Forty-one new measurements of the mass of individual cosmic ray mesotrons have been obtained with the equipment previously described. The cloud chamber in the magnetic field was filled with air at 1.13 atmosphere. A curvature correction of 0.03 ± 0.04 meter^{-1} has been derived from the measurement of 60 no-field tracks. The 41 particles whose mass has been determined have energies in the range 50 to 600 Mev and radii of 4750 gauss. The probable errors due to turbulence are 3 to 8.5 percent and are much larger than the scattering probable errors which are 1.5 to 2.5 percent for this energy range. 37 of the 41 measurements are consistent with the assumption of a unique mass of $192m_e$. The probable error based on external consistency is $\pm 5m_e$. The remaining four mass values (474, 538, 588, $717m_e$) do not seem to be consistent with the other observations. The 37 values from this experiment and the 26 measurements of W. B. Fretter[1] are consistent with the assumption of a unique mass of $196 \pm 5m_e$.

* The research described in this abstract was supported in part by the Office of Naval Research.
[1] W. B. Fretter, Phys. Rev. **70**, 625 (1946).

B8. An Apparatus for Mesotron Mass Measurements at High Altitudes.* R. B. BRODE, *University of California.*—

To measure the momentum of cosmic-ray particles, cloud chambers have been mounted above and below the gap in a permanent magnet. Thin beryllium foil windows separate the cloud chambers from a helium filled box in the gap of the permanent magnet. The change in direction of the particles above and below the magnet can be accurately measured. The induction in the magnet gap is about 5000 gauss. 20 cm of track are visible in each chamber, and about 20 cm are obscured by the magnet between the chambers. Below this set of chambers is placed a large cloud chamber containing 15¼-inch thick lead plates. The range of a particle that passes through the momentum analyzer is observed in the lower chamber. The entire apparatus with its controls occupies a space of about 75 cubic feet, and is mounted on a rigid framework for installation in a B-29. The weight of the apparatus is about 2000 pounds. Sea level operation of this unit furnishes about one measurable mass value per day out of 125 coincidence-tripped observations. The spectrum of low energy mesotrons now indicates that one should, at 30,000 feet, measure about 15 mass values per hour out of 30 counter-controlled expansions. The measurements of masses with this apparatus appears to be about as reliable as the data obtained in this laboratory with a large electromagnet and cloud chamber for range determination.

* The research described in this abstract was supported in part by the Office of Naval Research.

B9. Some Discharge Characteristics of Geiger-Müller Counters. H. V. NEHER, *California Institute of Technology.*—For the usual self-quenching or fast cylindrical Geiger counter for a given potential above threshold, there is a definite relationship between the duration, τ, of the pulse, the maximum change in potential of the wire, ΔV, and the resistance in the circuit. It is found that $\Delta V\tau/R$ is approximately a constant, independent of the capacitance in the circuit. This is to be expected if the quantity of charge that flows is independent of the circuit constants. For a counter 6″ long, 1″ in diameter and a wire 0.0015″ in diameter working at 150 volts above threshold, $\Delta V\tau/R$ was found to have an average value of 2.6×10^{-9} coulombs.

B10. New Measurements on the Variation with Latitude of the Cosmic-Ray Intensity at the Vertical at High Altitudes. A. T. BIEHL, R. A. MONTGOMERY, H. V. NEHER, W. H. PICKERING, WM. C. ROESCH, *California Institute of Technology.*—To achieve a higher degree of accuracy combined with a better angular resolution than could be achieved with the equipment used by Millikan, Neher and Pickering[1] in 1939–42 in their balloon flights, apparatus of an entirely new design was constructed. Three trays of counters were used consisting of 8 counters in each. Each tray had a sensitive area of approximately 25×25 cm^2. The distance between the outside trays was 1 meter. This arrangement gave an angular resolution of approximately $\pm15°$ from the vertical. To achieve constancy of counter voltage, light weight dry cells were used. The whole equipment including wrapping and lines ready for launching weighed about 8 kg. At least two flights, measuring the radiation coming in near the vertical, were made at San Antonio, Fort Worth, St. George (Utah), Omaha, Rapid City, Bismarck and Saskatoon. Preliminary results from these flights will be presented.

[1] H. V. Neher and W. H. Pickering, Rev. Sci. Inst. 13, 143 (1941). See also W. H. Pickering, Proc. I.R.E. 31, 479 (1943).

B11. Stars in Photographic Emulsions. Part 1. Experimental. EUGENE GARDNER AND VINCENT PETERSON, *University of California.*—Photographic plates have been bombarded in the 184″ Berkeley cyclotron for the purpose of studying stars initiated by deuterons and alpha particles. We have tabulated the number of prongs (i.e., the number of charges particle tracks making up the star) for 1200 stars initiated by deuterons and 200 stars initiated by alpha particles. Protons of energy more than about 10 Mev do not make recognizable tracks in the emulsions which we are using, so our results will not include prongs due to high energy protons. For stars initiated by deuterons the average number of prongs per star is 3.0. This is true for all incident deuteron energies from 35 Mev to 190 Mev. Preliminary results indicate that for stars initiated by alpha particles the average number of prongs is slightly higher. For deuteron-initiated stars there are about three times as many prongs in the direction of the beam as in the backward direction. The cross section for formation of stars by alpha particles is being measured by counting sections of tracks made by alpha particles and the stars originating on these tracks. This paper is based on work performed with the support of the Atomic Energy Commission under Contract W-7405-Eng-48 with the Radiation Laboratory, University of California, Berkeley, California.

B12. Stars in Photographic Emulsions. Part II. Theoretical. WENDELL HORNING, *University of California.*—The number of stars observed as a function of the number of prongs has been computed on the basis of a nuclear model described by R. Serber.[1] The method of the calculation is to compute first the distribution of excitation energies of a nucleus, for a given energy of the bombarding particle. The statistical model is then used to predict what particles will be evaporated from the nucleus at each excitation. The average number of prongs per star thus obtained varies somewhat with energy, from 3.0 for 35 Mev deuterons to 3.9 for 190 Mev deuterons. This agrees roughly with the observed average prong number of 3.0 for all incident energies used. Since the ratio of neutron to charged particle evaporation is greater for heavier elements, the lighter elements in the photographic emulsion contribute strongly to the visible stars. The recoil of these lighter nuclei accounts roughly for the observed angular distribution of star prongs, if we assume that evaporation is spherically symmetric with respect to the parent nucleus. This paper is based on work performed with the support of the Atomic Energy Commission, under Contract W-7405-Eng-48 with the Radiation Laboratory, University of California, Berkeley, California.

[1] R. Serber, Phys. Rev. 72, 1114 (1947).

SATURDAY MORNING AT 9:30

Room 19, Chemistry Building

(L. A. DUBRIDGE presiding)

Invited Papers

C1. Nuclear Transmutations with High Energy Particles. G. T. SEABORG, *University of California, Berkeley.* (30 min.)

C2. The Metabolism of the Fission Products and the Heaviest Elements. J. G. HAMILTON, *University of California, Berkeley.* (30 min.)

Contributed Papers

C3. Heavily-Ionizing Cosmic-Ray Particles at 30,000 Ft. Altitude.* R. RONALD RAU,** CARL D. ANDERSON, RAYMOND V. ADAMS, AND PAUL E. LLOYD, *California Institute of Technology.* Out of 3914 cloud-chamber photographs obtained in a B-29 aircraft at 30,000 ft. altitude, 378 photographs show the occurrence of single heavily-ionizing particles which cannot arise from radioactive contamination, and 72 photographs each show from 2 to 17 particles which arise from nuclear disintegrations in the walls or the gas of the cloud-chamber. Of the singly occurring particles 79 are identified as protons and 9 as mesotrons. The particles which are observed to arise from disintegrations are protons in all cases where identification is possible. The heavily-ionizing particles of low energy (of energy up to 20 Mev) occur isotropically; those of higher energy favor the vertical direction, and in only 3 percent of the cases are they time-coincident with electron showers. Heavily-ionizing particles are observed 7.2 times as frequently per exposure at 30,000 ft. as at 14,000 ft.

* This work was carried out under contract with the Office of Naval Research.

** Now at the Princeton University.

C4. Photoeffects in Middle-Weight Nuclei. L. I. SCHIFF, *Stanford University.*—Recent data[1] on photoeffects in light and middle-weight nuclei obtained with Li γ rays give considerably larger values for the ratio $\sigma(\gamma, p)/\sigma(\gamma, n)$ than predicted by the usual statistical theory.[2] This theory assumes that all states of the two residual nuclei can arise from the states of the compound nucleus initially excited. Excitation by a γ ray whose wave-length is greater than the nuclear radius is expected to yield compound states that correspond to a more regular kind of oscillation than those excited by nucleon bombardment. We suppose that most of the states of the residual nuclei from the photoeffects have similar regularities. The effective level densities then increase only as a small power of the excitation energy, rather than exponentially as in the case of nucleon bombardment. This shifts the spectrum of emitted protons and neutrons towards higher energies, and increases the cross section ratio since the protons can penetrate the Coulomb barrier more easily. Numerical estimates agree in order of magnitude with the experiments, and are insensitive to the power of the energy in the level density.

[1] O. Hirzel and H. Wäffler, Helv. Phys. Acta (to be published).
[2] V. F. Weisskopf and D. H. Ewing, Phys. Rev. **57**, 472 (1940).

C5. The Berkeley Four Million Volt Electrostatic Generator. CLARENCE TURNER, BRUCE CORK, JOSEPH BALLAM, AND HAYDEN GORDON, *University of California.*—The Berkeley pressure Van de Graaff machine was designed to inject 4-Mev protons into the linear accelerator. The Wisconsin horizontal design was extrapolated to insure dependable operation at 4 million volts. The pressure tank is 8 feet inside diameter, with a maximum operating pressure of 200 p.s.i.g. The 20″ air gap between high potential electrode and tank is divided into two 10″ gaps by a second shell operating at half the total voltage. The length of insulating column is 15 feet. The high potential electrode is 54″ o.d. and 6 feet long to provide space for extensive equipment for operation of a high current pulsed ion source. Provision was made for two accelerating tubes—one for the proton beam and one for an electron beam to be used for voltage control. Reasonably dependable operation at 4 million volts has been attained with 100 p.s.i.g. nitrogen pressure and about 40 pounds of freon. Proton beams of several microamperes have been obtained, but results are very preliminary. This work was sponsored by the Atomic Energy Commission.

C6. Ion Source Equipment for Berkeley Electrostatic Generator. FRANKLIN FILLMORE, ARTHUR HUDGINS, AND MORRIS JEPPSON, *University of California.*—The ion source in this generator was designed to produce high current proton pulses 15 times per second and of 300 microseconds duration. This permits a high injection current during the on time of the linear accelerator without overloading the electrostatic generator. The protons are generated in a Zinn-type arc equipped with a differential pumping system which removes 95 percent of the H_2 gas escaping from the arc chamber. The protons are accelerated to 50 kv and focused into the accelerating tube through a small aperture. The differential pumping system consists of an air-cooled diffusion pump backed by a mechanical pump operating inside a small steel tank. Hydrogen pumped from the ion source discharges into this tank and is recirculated to the ion source through an oil filter and palladium leak. Power to operate the equipment is provided by two 400-cycle generators driven by the charging belt. Cold air from a heat exchanger is blown through the textolite support tubes to cool the diffusion pump and other shell equipment. Control

is accomplished by small d.c. motors which are switched on and off by a selector switch system which in turn is operated by a nylon fishline. This work was sponsored by the Atomic Energy Commission.

C7. Physical Design of the Berkeley Linear Accelerator. HUGH BRADNER, RICHARD CRAWFORD, HAYDEN GORDON, AND JOHN R. WOODYARD, *University of California.*—Thirty-two megavolt protons have been obtained from a resonant cavity linear accelerator. The cavity is a 12-sided copper cylinder approximately 40 feet long and 38 inches in diameter, operating at 202.5 mc in the TM_{010} mode which has a Q of about 70,000 and shunt impedance of 480 megohms. Protons are injected on the axis and accelerated in the gaps between 46 "drift tubes." These tubes range in diameter from 4.75" to 2.75" and in length from 4.4" to 10.9", and in center-to-center distance from 5.43" to 14.5". Tube dimensions were chosen to maintain the resonant frequency of the cavity constant throughout its length. Tungsten wire grids are used for focusing. Drift tubes are supported by conducting stems which permit accurate adjustment of drift tube position. Peak power of 1.5 megawatts is supplied by 24 triode oscillators through 24 transmission lines terminating in low-inductance loops inside the cavity. The cavity is supported in a steel tank which is evacuated to a working pressure of 10^{-5} mm mercury. Both the vacuum tank and the resonant cavity split longitudinally for access. This work was sponsored by the Atomic Energy Commission.

C8. Control of the Field Distribution in the Linear Accelerator Cavity. WOLFGANG K. H. PANOFSKY, CHAIM RICHMAN, AND FRANK OPPENHEIMER,* *University of California.*—The cavity of the 40 foot linear accelerator consists of a long cylindrical pipe loaded with "drift tubes" of graduated lengths.** Such a system has a spectrum of resonant modes near the desired operating mode, which is the mode giving uniform peripheral magnetic flux-density as a function of the axial co-ordinate. The spectrum becomes more closely spaced as the length increases. Analysis of the field-equations in the cavity has shown that the critical problem is not the problem of preventing jumping of the frequency from the proper mode to the next mode, but is the problem of controlling the uniformity of field distribution in the proper mode. This problem has been analyzed by means of simple perturbation theory. This method results in a simple procedure of adjusting the distribution using a Fourier analysis of the magnetic field distribution at the edge of the cavity. The procedure has been used experimentally with satisfactory results. The mechanical tolerances of the accelerator cavity and the problems associated with multiple cavity coupling can be studied by this method. This work was sponsored by the Atomic Energy Commission.

* Now at the University of Minnesota, Minneapolis, Minnesota.
** Phys. Rev. **70**, 447(A) (1946).

C9. Linear Accelerator Oscillator and Coupling System. W. R. BAKER, J. V. FRANCK, AND J. D. GOW, *University of California.* (Introduced by Dr. L. W. Alvarez.)—An oscillator capable of delivering 150 kw of 200 mc radio frequency power into the high "Q" resonant load of the linear accelerator has been developed. This oscillator, using four GL-434A triodes in parallel, is operated with a pulse length of 300 microseconds and a pulse repetition rate of 15 c.p.s. The operating frequency is controlled primarily by the linear accelerator cavity. A 50 ohm co-axial transmission line approximately one wave-length long and essentially unity coupled to the oscillator, operates with a voltage standing wave ratio of about 7 to supply power to the coupling loop in the linear accelerator. A resistor is placed across the transmission line at a voltage minimum for the fundamental frequency to suppress the unwanted 170 mc and 260 mc modes of the oscillator. This resistor absorbs less than three percent of the power in the fundamental frequency. The oscillator has been designed to have optimum grid drive at high power level and so requires pre-excitation to obtain short build-up time. No problem is encountered in phasing 24 oscillators which automatically lock into the resonant frequency of the cavity. This work was sponsored by the Atomic Energy Commission.

C10. Beam Dynamics in the Linear Accelerator. ROBERT SERBER, *University of California.*—The orbits of particles in the linear accelerator are stable, both for displacements in phase and for radial displacements from the axis of the machine. Stability in the latter case is achieved by the use of grids or foils in the drift tubes. The lengths, L, of the drift tubes form a linear progression, $L=l_1 n$. For small displacements, the frequency of phase oscillation is $\nu=(\cot\phi_s/2\pi n)^{\frac{1}{2}}$, where ϕ_s is the synchronous phase, and the amplitude of oscillation is $A\sim(n^{3-2\zeta}\cot\phi_s)^{-\frac{1}{4}}$. Here ζ is a number which depends on the shape of the field in the accelerating gaps ($\zeta<0.2$ in the present machine). For the radial oscillations, $\nu=(1/2\pi)(K/n)^{\frac{1}{2}}$ and $A\sim(n/K)^{\frac{1}{4}}$ where K is a number of order one which depends on field shape. Multiple scattering in the foils would cause the beam to spread to a diameter d; $d^2=[(32\pi NtZ^2e^2/KE^2)\times\ln(4\pi NtZ^{4/3}\hbar^2/m^2v^2)][(n/n_1)^{\frac{1}{2}}-1]$. Here t is the thickness of a foil, E is the mean accelerating electric field, and n_1 is the number of the first drift tube. If a is the internal diameter of a drift tube, the fraction of the beam transmitted is $I/I_0=1.6\exp\{-1.45d^2/a^2\}$. This work was sponsored by the Atomic Energy Commission.

SATURDAY AFTERNOON AT 2:00

Room 19, Chemistry Building

(J. KAPLAN presiding)

D1. Near Infra-Red Dichroism Involving Aligned CH_2 Groups. LEONARD GLATT, *University of California.* (Introduced by Joseph W. Ellis.)—An investigation of dichroism in substances containing aligned single bond CH_2 groups is being conducted. Marked dichroism has been found in stretched polyethylene films, the *E*-vector being oriented respectively parallel and perpendicular to the molecular chain axes (stretch direction). Some assignments of observed bands to combination and overtone modes of CH_2 oscillators were attempted. Polarization evidence of coupling between CH_2 groups is presented. An interesting band, present only when there is an *E*-vector component parallel to the molecular chain axis was found at 4216 cm^{-1}. Semi-crystalline "parowax" films from 40 to 500μ thick have been prepared by slowly cooling a melt on a hot water surface. Spectrograms of these films with unpolarized light, in conjunction with spectrograms of polyethylene with polarized light, gave convincing proof of an excellent alignment of the molecular chain axes normal to the surface.

D2. Geometrical Optics of Grazing Incidence Reflectors. PAUL KIRKPATRICK, A. V. BAEZ, AND ALLEN NEWELL, *Stanford University.*—Production of mirror images with x-rays is subject to the restriction that grazing angles of incidence must not exceed the small critical angle of total reflection. Such cases seem to have been neglected by optical theorists. A spherical mirror possesses the two focal lengths $Ri/2$ and $R/2i$, where R is the radius of curvature and i the grazing angle. Convergence of the former type readily produces a real line image of a point source. Two crossed mirrors yield a point image. Focal length, being dependent upon i, is conveniently variable. Two crossed mirrors produce anamorphotic images of extended objects, but this defect may be corrected by use of a third mirror. As with the concave grating, the focal surface is steeply inclined to the principal ray, but this may be reduced by successive reflections from two mirrors in the parallel position, an arrangement which also reduces spherical aberration. This aberration, unlike that of the paraxial case, is in the sense that perpheral rays intersect at a greater distance from the mirror than do central rays. This causes pronounced doubling of images beyond the point of best focus. Presently recognized limitations would hold speeds to the order of $f/100$.

D3. Effect of Water of Crystallization on Absorption Bands of Neodymium Bromate Crystals. ARNOLD BENTON AND E. L. KINSEY, *University of California.*—Experimental evidence of the coupling of the 3μ vibrations of the water molecule with electronic transitions of the Nd^{+++} ion in $Nd(BrO_3)_3 \cdot 9H_2O$ crystals was obtained. The evidence is provided by the shifting of certain lines when H_2O is replaced by D_2O in the crystals, by the fact that the spacings of these lines agree with those known to be caused by pure electronic transitions, and by the fact that the displacements of these lines from the electronic lines are in good agreement with the known values of the vibration frequencies of water. The lines have been observed in the visible region of the spectrum at liquid nitrogen temperature using polarized light. As in the case of the pure electronic lines, the intensities are functions of the direction of the polarization of the light relative to the hexagonal axis of the crystal.

D4. Stellar Electromagnetic Fields. LEVERETT DAVIS, JR., *California Institute of Technology.*—The electromagnetic field in the neighborhood of a rotating magnetized body such as the earth or sun is best treated in an inertial system, one that does not rotate with the body. The stellar model considered is one in which the magnetic field is that of a dipole parallel to the axis of rotation, the field strength at the surface of the star at the pole being B_p. Rationalized m.k.s. units will be used. If the field due to the ions in the neighborhood of the star is negligible, the electrostatic potential outside the star is $V = V_p(a/r)^3 P_2(\cos\theta)$ where $V_p = B_p \omega a^2/3$, a is the radius of the star, ω its angular velocity, and (r, θ, ϕ) are spherical polar coordinates. Consideration of the motion of the ions in such a field shows that a space change will accumulate that cannot be neglected. When a steady state has been attained, if one neglects the effect of unionized interstellar material, it appears that the external space charge rotates with the same angular velocity as does the star, that the change in the magnetic field is very small, but that the electrostatic potential is now, to a first approximation, $V = -V_p(a/r)\sin^2\theta$.

D5. Rates of the Carbon Reactions in the Sun. REVEREND J. O'REILLY AND R. F. CHRISTY, *California Institute of Technology.*—Recent measurements in this laboratory (to be published soon) on the reactions C^{12} plus protons and C^{13} plus protons in the region of .4 to 1.3 Mev have led to values for the proton width Γ_p of 35 and 40 kev at their respective resonances at .45 and .55 Mev. The use of these values, together with the γ-ray widths which were confirmed to be .63 and 15 ev respectively, permits an estimate of the rates of these reactions in the sun. The cross sections were extrapolated to the very low energies associated with stellar reactions by means of the one level dispersion formula. This procedure is admittedly crude but is perhaps the best that can be done in the absence of actual measurements at lower energies. The new value for the rate of the C^{13} reaction is 40 times that obtained by Bethe, by using a rough general estimate of Γ_p. The ratio of the rates of the

C^{13} and C^{12} reactions is 9 whereas the inverse abundance ratio on the earth is 90. The rate of the C^{12} reaction compared to the $N^{15}(p\alpha)$ reaction is now however 3×10^{-4} which corresponds more nearly to their abundance ratio. This work was carried out under contract with the Office of Naval Research.

D6. Investigation of a Lens Type β-Ray Spectrograph. T. LAURITSEN AND R. F. CHRISTY, *California Institute of Technology.*—A lens type β-ray spectrograph able to focus electrons of energy up to ~3 Mev has been constructed to investigate low energy γ-radiation and to study various design parameters such as spherical aberration, background, etc. Calculations of the spherical aberration of a magnetic field with a minimum at the center of the spectrograph have been made.[1] Variation of the shape of the magnetic field has been accomplished by axial separation of the two coils which constitute the magnetic lens resulting in a considerable increase in the ratio of intensity to aberration over that obtained with a single thin lens. These considerations are being applied to the design of a high energy spectrograph intended to focus electrons up to 17.5 Mev. This work was carried out under contract with the Office of Naval Research.

[1] Kai Siegbahn, Phil. Mag. **37**, 162 (1946).

D7. Proton Scattering by Beryllium. GEORGE S. KENNY AND SYLVAN RUBIN, *California Institute of Technology.*—The angular distribution of protons scattered from thin beryllium foils has been measured in the range 720 to 1310 kev, at angles of 25° to 155°, using a photographic type scattering camera. The camera used for previous work on Be^9 scattering has been modified by the addition of a drum shaped plate holder which permits 5 exposures before reloading. Observations have been made at significant points of the proton excitation curve, discussed in an accompanying abstract by R. G. Thomas, W. A. Fowler, and C. C. Lauritsen. The effect of the narrow γ-ray resonances at 988 and 1077 kev has been investigated in detail. Bombarding energies were accurately determined by measurement of the γ-ray excitation curve just prior to exposure of the plates. This work was carried out under contract with the Office of Naval Research.

D8. Beryllium-Proton Reactions and Scattering. R. G. THOMAS, W. A. FOWLER, AND C. C. LAURITSEN, *California Institute of Technology.*—The cross sections of the reactions $Be^9(p, d)Be^8$ and $Be^9(p, \alpha)Li^6$ and of the scattering $Be^9(p, p)Be^9$ have been measured for bombarding proton energies from 500 to 1200 kev at 90° and 135° to the incident beam. The protons, deuterons, and alpha-particles were separated by magnetic analysis. In this region the $Be^9(p, \gamma)B^{10}$ reaction shows marked resonances at 988 and 1077 kev.[1] The scattering cross section shows anomalies corresponding to these resonances. The anomaly corresponding to the wide resonance at 988 kev is very large, the ratio to Rutherford scattering at 135° varying from a minimum of 2 at 910 kev to 6 at 1020 kev. The corresponding scattering cross sections are 1 and 3 barns. The deuteron and alpha-particle cross sections are of the order of 0.1 barns with the deuteron yield curve showing marked variations while the alpha-particle curve does not. This work was carried out under contract with the Office of Naval Research.

[1] C. C. Lauritsen, T. Lauritsen, W. A. Fowler, Phys. Rev. **72**, 739 (1947).

D9. Catalytic Isomerization of Propane Containing C^{13}. O. BEECK, J. W. OTVOS, D. P. STEVENSON, AND C. D. WAGNER, *Shell Development Company.*—Using propane containing 17 percent C^{13} in the end position, the moist aluminum bromide catalyzed isomerization to propane containing C^{13} in the middle position has been shown to occur in this three-carbon molecule at a rate comparable to ordinary normal-isobutane isomerization under the same conditions. Tracing the carbon atom shift was accomplished in a single step by the mass spectrometer (see following abstract), the change in the ratio of the intensities of the ionic fragments of mass 30 and 29 being a measure of progress toward equilibrium. Direct proof has been obtained that the isomerization reaction is intramolecular in character; no detectable increase in the number of propane molecules containing two C^{13} atoms (ion weight 46) was obtained after 600 hours at room temperature, although after only 65 hours the isomerization reaction had proceeded half way to equilibrium. No side reactions were observed. This technique is now being applied to the butane isomerization reaction.

D10. Analyses of Isotopic Propanes. D. P. STEVENSON, *Shell Development Company.* (Introduced by O. Beeck.)—In order to determine mass spectrometrically the isotopic species of a substance, one of the following two conditions must obtain: (a) Isotopic substitution must leave unchanged the dissociation probabilities of the various bonds of the molecular ion produced by low energy (50–100 volt) electron impact, or (b) samples of all isotopic species of interest must be available for calibration purposes. It has long been known that condition (a) does not hold for deuterium substituted compounds and thus that (b) must be satisfied for such compounds. Heretofore it has been necessary to assume that condition (a) holds for substances in which C^{12} has been replaced by C^{13}, although small deviations would be expected on theoretical grounds. Comparison of the mass spectrum of a propane with an abnormal terminal C^{13} content (see preceding abstract) with the mass spectrum of ordinary propane indicates that the dissociation probabilities of C—H bonds are unchanged within the experimental error. However, it is found that the dissociation probability of the $C^{12}-C^{12}$ bond in the isotopic propane is slightly greater, 4–5 percent, than that of a $C^{12}-C^{12}$ bond in ordinary propane. Although the complementary decrease of the dissociation probability of the $C^{12}-C^{13}$ bond is indicated, the concentration of C^{13} available for this investigation is too low to permit quantitative evaluation. The analytical implications of these observations will be discussed.

D11. Ionization by C^{14} Radiation in the Ionization Chamber. JOHN W. OTVOS, *Shell Development Company.*

(Introduced by O. Beeck.)—In order to measure C^{14} concentrations in gases by the ionization chamber technique, the relative ionization probabilities of ten hydrocarbons and of CO_2, CO, N_2, O_2, N_2O, He, Ne, and A have been determined for the beta particles emitted by C^{14}. $C^{14}O$ and $C^{14}O_2$ were used as the source for beta particles. The results show several expected regularities: (1) For the series of hydrocarbons the ionization probabilities increase linearly with the number of valence electrons. (2) For gases composed of the neighboring elements carbon, nitrogen, and oxygen the ionization probabilities obey simple additivity relationships based again on valence electrons. (3) Although methane and neon are isoelectronic the value for methane is considerably higher due to the lack of centralization of nuclear charge. Ionization probabilities measured at the relatively high energies of C^{14} beta particles bear no relation to ionization potentials or chemical properties but seem rather to be governed by quasi-geometrical factors, such as molecular volume. Interpolation of ionization probabilities for high electron energies should be possible on the basis of valence electrons, distribution of nuclear charge, and position in the Periodic Table, with values for helium, neon, and argon serving to relate the first, second, and third rows.

D12. The Bulk Viscosity of Liquids.* L. N. LIEBERMANN, *University of California.*—The existence of bulk viscosity in liquids has been suggested as a possible explanation for the disagreement between the absorption of sound calculated from shear viscosity and the observed absorption. Eckart[1] recently has shown that forces responsible for streaming of fluids caused by sound waves are viscous forces of the bulk as well as the shear type and suggested that streaming might be used for their measurement. The velocity of streaming in a fluid is proportional to the power in the sound beam and to b where $b=(\frac{4}{3}\nu+\nu')/\nu$ and ν and ν' are the coefficients of shear and bulk viscosity. Whenever viscosity alone is responsible for sound absorption b is also the ratio of the observed absorption to that calculated using shear viscosity. The quantity b may be obtained from the ratio of the streaming pressure to the radiation pressure, together with an observation of the streaming velocity. The latter is obtained by suspending finely divided particles in the liquid and photographing their motion. The ratio of the pressures is obtained by suspending a disk in the axis of the sound beam. The disk is supported by strain gauge wire so that forces on the disk result in changes in resistance of the wire. In order that the relatively large radiation pressure effect produce a force on the disk of the same order as the streaming pressure, the reflectivity of the disk was made small by using aluminum foil of known thickness. Preliminary results show that b for CCl_4 is of the order of 13; this is in agreement with b calculated from sound absorption data. Values for other liquids are being determined.

* This work represents one of the results of research carried out under contract with the Bureau of Ships, Navy Department.

D13. The Stability of Gas Bubbles in Water.* E. GERJUOY, *University of Southern California.*—Values of the tensile strength of water range from 0 to 200 atmospheres depending on the observer and the method of measurement.[1] To account for these discrepancies, the presence of minute bubbles in the water, which expand rapidly at some critical negative pressure, has been hypothesized. To investigate this question, calculations have been made on the following idealized problem. A bubble of an ideal insoluble gas is in equilibrium under an external pressure of one atmosphere, the surface tension T being 75 dynes/cm. The external pressure is then slowly decreased, the bubble expanding isothermally in accordance with the ideal gas law. For positive external pressures the bubble always has an equilibrium radius, but for sufficiently large negative pressure there is no equilibrium radius, and in fact the bubble becomes unstable and grows rapidly when $pr+4T/3\sim 0$. The smaller the bubble at atmospheric pressure, the greater the negative pressure required to produce instability. However an initial bubble radius of 5×10^{-5} cm produces breakdown at a negative pressure of one atmosphere, while to postpone breakdown to negative pressures greater than 100 atmospheres, the initial "bubble" radii must be less than 5×10^{-7} cm. Although the model is crude, these results support the view that rupture will be observed at relatively small negative pressures unless the liquid is thoroughly degassed.

* This work supported by the Office of Naval Research.

[1] H. N. V. Temperley and Ll. G. Chambers, Proc. Phys. Soc., London **58**, 420 (1946).

D14. Measurement of Tensile Strengths of Liquids by Centrifuge Method.* J. J. DONOGHUE, E. GERJUOY, AND R. E. VOLLRATH, *University of Southern California.*—Measurements of the tensile or rupture strength of water and benzene have been made, using a centrifuge. A tube of liquid is rotated about a vertical axis, the speed of rotation being slowly increased until rupture is observed. The rupture manifests itself by the appearance of a bubble at the center of rotation, easily visible with the naked eye. The centrifuge speed is measured with a stroboscope, and the tensile strength at rupture is then readily calculable from the known length of the liquid column and the r.p.m. at rupture. Test specimens are prepared in a closed outgassed system. The liquids are distilled in a fractionating column to remove gases and other impurities. A tube of liquid is then sealed off while in equilibrium with a known small air pressure. Initial results with partially degassed water confirm predictions that the observed rupture strength is greatly lowered by the presence of dissolved gases and/or gas nuclei.

* Work supported by the Office of Naval Research.

SATURDAY AFTERNOON AT 2:00

* Room 29, Physics-Biology Building

(R. B. BRODE presiding)

E1. The Dynamics of Large Horizontal Eddies (Axis Vertical) in the Ocean off Southern California. GEORGE F. MCEWEN, *University of California.*—The circulation at depths zero and fifty meters is characterized by large horizontal counter-clockwise eddies between a northward inshore current and a southward offshore current. The eddy velocity decreases and the eddy size increases over a period of several months. Equivalent circular eddies computed from the usually oval shaped ones serve as convenient models for mathematical investigation. Each series of eddies conformed to the principle of the conservation of the moment of momentum, and their kinetic energy decreased progressively in accordance with a law of energy dissipation expected from a coefficient of lateral turbulence, 10^5 c.g.s. Next, a transformation of the two hydrodynamical equations of horizontal motion in the sea, involving both the deflecting force due to the earth's rotation, and lateral turbulence, resulted in the following single differential equation of vorticity diffusion:

$$\frac{\partial \zeta}{\partial t}=\mu\left(\frac{\partial^2\zeta}{\partial r^2}+\frac{1}{r}\frac{\partial \zeta}{\partial r}\right)+2\frac{\partial \mu}{\partial r}\frac{\partial \zeta}{\partial r}+\zeta\left(\frac{\partial^2\mu}{\partial r^2}+\frac{1}{r}\frac{\partial \mu}{\partial r}\right).$$

The theoretical relation of velocity to distance from the center corresponding to a solution assuming $\mu=10^5$ c.g.s. with boundary conditions, $t=0$, $\zeta=\zeta_1$, $r=r_1$, $\zeta=0$, $r>r_1$, agreed well with observations.

E2. Use of Plasma Sheaths as Variable Capacitances. W. E. PARKINS AND J. M. LEFFLER, *University of Southern California.*—The problem of cyclotron frequency modulation brought forth an unpublished suggestion by R. L. Thornton and B. Peters that the speed and magnitude of the frequency variation required might be achieved using controlled changes in the thickness of a plasma sheath serving as a capacitance. Some study of the feasibility of capacitance variation by such an approach has been made. Any current receiving electrode placed in a gas discharge will have a capacitance which depends on the discharge operating conditions. This capacitance also depends on the applied frequency as can be illustrated in the case of a flat probe maintained negative with respect to the plasma. At very high frequencies the capacitance will be determined by the space charge oscillations of the electrons.[1] At somewhat lower frequencies the electrons will continuously assume new equilibrium positions, but the ion current to the probe will be nearly steady. In this range the capacitance may be estimated by treating the sheath as the gap of a vacuum condenser. This has been verified in frequency modulation experiments. At still lower frequencies the sheath boundary will be able to adjust continuously. Here variations in ion current to the probe during the adjustment become important and calculations show the capacitance can be large compared to that indicated by the sheath dimensions. Circuits and operating data will be given.

[1] Tonks, Phys. Rev. **37**, 1458 (1931).

E3. Workfunctions of a Gas-Coated Surface. G. L. WEISSLER AND R. W. KOTTER, *University of Southern California.*—By using C. W. Oatley's[1] method for measuring contact potentials between a surface and a hot W-filament ($\phi_W=4.67$ ev), we determined the average workfunctions, ϕ, of a Ta-surface (slightly contaminated with W) after the following treatments: (1) baked out at 400°C for 24 hrs., heated to 1100°C by electron bombardment for 40 min.: $\phi=4.77$ ev; (2) surface bombarded with N_2 glow-discharge: $\phi=4.43$ ev; (3) surface heated by electron bombardment: $\phi=4.77$ ev; (4) surface bombarded with argon glow-discharge: $\phi=4.71$ ev; (5) surface heated by electron bombardment: $\phi=4.66$ ev; (6) surface bombarded with O_2 glow-discharge: $\phi=5.87$ ev; (7) surface bombarded with argon glow-discharge: $\phi=4.62$ ev; (8) surface heated by electron bombardment: $\phi=4.71$ ev, and later $\phi=5.03$ ev (this latter increase in ϕ is due to residual O_2 diffusing to the surface); (9) surface bombarded with H_2 glow-discharge: $\phi=4.20$ ev, and later $\phi=4.50$ ev; (10) surface heated by electron bombardment: $\phi=5.38$ ev, and later $\phi=5.29$ ev.—N_2 and H_2 lower ϕ significantly, O_2 raises it. The lowering due to H_2 would have been greater if it were not for the previous O_2 treatment. Further similar work on evaporated metal surface is in progress.

[1] C. W. Oatley, Proc. Phys. Soc., London **51**, 318 (1939).

E4. Isotope Shifts in Some Previously Unexplored Lines of Nitrogen.* JOHN R. HOLMES, *University of Southern California.*—By using the Hilger E478 spectrograph in series with a Fabry-Perot interferometer it has been found possible to measure the isotope shifts in lines of N I which were previously unmeasured because of their low intensity and also the large dispersion required.[1] The lines could be obtained with high intensity and very few background N_2 bands by exciting a mixture of 0.01 mm N_2 and 4–6 mm He with an electrodeless discharge of about 30 megacycles. In order to get lines sharp enough to resolve the isotope structure it is necessary to immerse the discharge in liquid nitrogen; furthermore a marked improvement in sharpness was found upon making the cross section of the tube a thin rectangle rather than a circle. Preliminary results are approximately:

Transition	Wave-length	Isotope shift	
$3p\ {}^4D_{5/2}\rightarrow 3s\ {}^4P_{5/2}$	8719*A*	-0.06 ± 0.01	(Shift toward longer wave-lengths from N^{14} to N^{15})
$3p\ {}^4D_{3/2}\rightarrow 3s\ {}^4P_{3/2}$	8711.9*A*	-0.06 ± 0.01	
$3p\ {}^4D_{1/2}\rightarrow 3s\ {}^4P_{1/2}$	8703.4	-0.06 ± 0.01	
$3p\ {}^4P_{3/2}\rightarrow 3s\ {}^4P_{3/2}$	8210.9	-0.05 ± 0.01	
$3p\ {}^4P_{3/2}\rightarrow 3s\ {}^4P_{1/2}$	8188.2	-0.05 ± 0.01	
$3p\ {}^4P_{1/2}\rightarrow 3s\ {}^4P_{3/2}$	8185.0	-0.05 ± 0.01	
$3p\ {}^4S_{3/2}\rightarrow 3s\ {}^4P_{1/2}$	7423.9	-0.04 ± 0.01	

It is intended to try the same method for a measurement of the isotope shift of $3s\,{}^1P_1 \rightarrow 2p\,{}^1S_0$ line of C I ($C^{12}-C^{13}$).

* This work has been partly supported by Contract ONR 238 Task III.

[1] J. R. Holmes, Phys. Rev. 63, 41 (1943).

E5. Graphical Evaluation of Jacobi Polynomials. S. LEROY BROWN AND MARY GOWEN FOULKS, *University of Texas.**—The Jacobi polynomials can be expressed in terms of the hypergeometric series** as

$$P_n(x)^{(\alpha,\beta)} = \binom{n+\alpha}{n} F\left(-n,\, n+\alpha+\beta+1;\, \alpha+1;\, \frac{1-x}{2}\right) \quad (1)$$

and will form an orthogonal set in the interval $+1$ to -1 with respect to the weight function $(1-x)^\alpha(1+x)^\beta$. Evaluation of such a polynomial may be accomplished with a mechanical harmonic synthesizer by the substitution $x=\cos\theta$, where the powers of $\cos\theta$ are expressed in terms of cosines of multiple angles. The ordinates of the continuous curve traced by the mechanical synthesizer give the values of the polynomial with respect to θ as the angle varies from 0 to π.

* Assisted by Office of Naval Research.
** Whittaker and Watson, *Modern Analysis*, Chap. XIV.

E6. A New Type of Dive Angle Indicator and Servo Accelerometer. DONALD H. JACOBS.* (Introduced by W. E. Frye.)—Work on a war time military research project revealed a need for a non-gyroscopic device for measuring the dive angle of aircraft and servoing this information at a high power level to other mechanisms. The device was required to remain unaffected by the forward acceleration of the aircraft in a dive. A need for a servo accelerometer also arose. Compactness and light weight were mandatory for both these devices. An instrument to meet these requirements was developed. The complete device, including a small servo motor with gear reduction, may be fitted into a standard aircraft instrument case. Several experimental models were built and were tested extensively in the laboratory and in aircraft. The theory of the instrument, data on sensitivity, design details, and the results of laboratory and field tests will be presented, together with some suggestions as to applications.

* Now at Aerophysics Laboratory, North American Aviation, Inc., Los Angeles, California.

E7. Metallic Carbide Lattice Energies and the Electron Affinity of C_2^{--}. I. HODES, *University of Southern California.* (Introduced by E. Gerjuoy.)—The fact that CaC_2 and other carbides form ionic crystals suggests that the structure C_2^{--} may be stable. The electrostatic energies of a number of carbides, specifically the crystals CaC_2, SrC_2, and BaC_2, have recently been calculated.[1] These calculations have been repeated by us, and the resultant values used to calculate the electron affinity E of C_2^{--}, defined by the equation $C_2^{--}+E=C_2+2e^-$. By analyzing a Born-Haber cycle for a metallic carbide, the expression $E+Q$, where Q is the heat of formation of molecular C_2 vapor from diamond, can be evaluated in terms of the crystal lattice energy U and known heats of formation. U equals the computed electrostatic energy plus corrections, the most important of which arises from the repulsive interaction. If the repulsive potential varies as $1/r^n$, a simple argument shows the correction should be $-1/n$ of the electrostatic energy. A value of $n=10$, indicated from other considerations, gives a result for $E+Q$ which for all three crystals is close to -245 kcal/mole. Q is not accurately known; the best available value yields $E=-2.9$ electron volts.

[1] L. I. Kazarnovskaya, J. Phys. Chem. U.S.S.R. **XX**, 1403 (1946).

E8. A Method for Incorporating into the Fourier Equations for X-Ray Studies Previously Established Structural Information. DAN MCLACHLAN, JR., *University of Utah*—When the structure of a compound is to be determined from x-ray data by use of the Fourier equations a great deal of computation is necessary in order to establish the $3-n$ parameters indicative of the coordinates of the atoms in the unit cell. When n is large the Patterson projections are often too complicated for interpretation. Although previously established structural knowledge (either from the organic chemist, electron diffraction, or x-ray diffraction) is commonly used qualitatively to assist in the trials or to recognize similarities in the projection, there have not to date been any procedures developed by which the known structural facts may be incorporated into the initial Fourier equations so that the number of parameters are reduced or the computations simplified. In this paper a procedure is described by which the known interatomic distances and angles are introduced at the start and only the unknown distances are involved in the computation. A many-atom problem of a large organic compound may be so reduced in unknown parameters by virtue of previously established knowledge that the Patterson synthesis is easily interpreted. The method is based on the postulate that if

$$\rho(u) = \Sigma_h\, F^2(h_{\sigma\sigma})\, \cos^2 2\pi h u,$$

then

$$\rho(u/g) = \Sigma_h\, F^2(h_{\sigma\sigma})\, \cos^2 2\pi h^* u,$$

where $h^*=gh$.

E9. Cyclotron Frequency Modulation. K. R. MACKENZIE, *University of California.*—A method of modulation with a frequency range of 2.4 to 1 has been developed in the Radiation Laboratory, making it possible for the 184-inch cyclotron to accelerate either protons or deuterons in the near future. The system utilizes a capacitor consisting of a rotor with 6 rows of blades, 50 blades to a row, which mesh with two stator rows. One stator row is held at one end of a large rectangular cross section transmission line, $\frac{1}{4}$ wave-length long, which is grounded at the other end. The other row is held at the end of a similar line which is connected to the dee. When fully meshed the whole system resembles a $\frac{1}{4}$ wave line. At the high frequency limit the system oscillates in approximately three $\frac{1}{4}$ wave sections with twice the dee voltage across the capacitor. Power is supplied by grounded grid tubes coupled to the resonant system by two lines whose lengths are adjusted to limit amplitude modulation to around 20 percent. This paper is based on work performed under Contract W-7405-eng-48B, with the Atomic Energy Commission.

E10. Scattering of High Energy Neutrons. A. BRATENAHL, R. H. HILDEBRAND, AND B. J. MOYER, *University of California.*—Measurements have been made of the angular distribution of high energy neutrons scattered into angles between 3° and 25° from spheres of Pb and Cu placed in the neutron beam of the 184-inch cyclotron. The scattered neutrons above 20 Mev were detected by pieces of carbon in which the $n, 2n$ reaction produces C^{11} which has a 20-minute half life. The experimental curves relating intensity with angle show widths and central amplitudes characteristic of diffraction patterns for the nuclear sizes involved. Nuclear radii for calculating the diffraction were those corresponding to one-half the total cross sections measured for Pb and Cu in this neutron beam by the same detectors.* An average value of wave-length for the neutrons of the beam was employed in the calculations. Theoretical curves have been adjusted to the experimental data for Cu and Pb separately, plotted on the basis of intensity per scattering atom. The ratio of the peak intensities at 0° from these curves, after correction for attenuation in the scatterer, is 4.05 ± 0.4. The predicted value for this ratio on the basis of diffraction by the nuclei is 4.16. Experimental pattern half widths at one-fourth of peak height are 6.5° and 11° for Pb and Cu, respectively; whereas for the adjusted theoretical curves the corresponding values are 7° and 10°. This paper is based on work done at the Radiation Laboratory of the University of California under Contract W-7405-Eng-48 with the United States Atomic Energy Commission.

* E. M. McMillan, D. C. Sewell, J. M. Peterson, L. J. Cook, Total Cross Sections for 90 Mev Neutrons, Phys. Rev. (to be published).

E11. Positive Temperature Coefficient of the Soft Component of Cosmic Rays. L. E. SMITH, JR.,* *University of Washington.*—Studies of the data from a cosmic-ray telescope correlated with surface air temperatures yielded a temperature coefficient for the soft component ($\frac{1}{2}$ to $10\frac{1}{2}$ cm lead) of $+.14 \pm .08$ percent/°C with an average correlation of $+.27 \pm .12$. Since the soft component is about 58 percent electrons from mesotron decay, 25 percent electrons produced by collision, and 17 percent slow mesotrons, there should be partial agreement of the coefficients of the soft component with the theory for coefficients of shower electrons produced by mesotron decay. This theory[1] predicts a difference between the electron and the mesotron component of -1.4 percent/cm Hg and $+.35$ percent/°C for the barometric and temperature coefficients. If for the mesotron coefficients we use the coefficients of the cosmic rays which penetrate $10\frac{1}{2}$ cm lead and for the electron component the coefficients of the soft component, we get $(-3.5 \pm 0.4) - (-1.8 \pm 0.2) = -1.7 \pm 0.6$ percent/cm Hg and $(+.14 \pm .08) - (-.13 \pm .05) = +.27 \pm .13$ percent/°C. These are in agreement with the values predicted by the above theory.

* Now at San Diego State College.
[1] J. Barnothy and M. Forro, Phys. Rev. **55**, 868 (1939).

E12. Recoil Protons in the Neutron Beam of the 184-Inch Cyclotron. WILSON M. POWELL, *University of California.*—A well collimated beam of neutrons from a half-inch beryllium target in the 195-Mev deuteron beam of the 184-inch cyclotron is allowed to pass through a Wilson cloud chamber. The beam enters the chamber through a 5-mil aluminum window. The chamber contains a half atmosphere of hydrogen as well as alcohol and water vapors and is in a magnetic field of 13,000 gauss. Measurements have been made of the angle and energy of recoil of the protons arising in the gas of the chamber. Curves will be given showing the distribution of the protons with angle and comparisons of these results with similar data obtained from carbon and paraffin with proportional counters will be made. This paper is based on work done at the Radiation Laboratory of the University of California under Contract W-7405-Eng 48 with the United States Atomic Energy Commission.

E13. Excitation of Na^{24} and Na^{22} by Deuteron and Alpha Bombardment of Al. A. C. HELMHOLZ AND J. M. PETERSON, *University of California.*—Using essentially the technique of Thornton and Senseman,[1] the yield of Na^{24} and Na^{22} as a function of the bombarding energy of deuterons and alpha-particles has been studied. The bombarded element was Al. After the decay of periods of a few minutes, half-life measurements identified the 14.8 hr. period of Na^{24} and a long period which chemistry showed to be Na (almost certainly Na^{22}). The energy of the incident deuterons was 190 Mev with a spread of about ± 5 Mev; of the alphas, 380 Mev with a spread of ± 10 Mev. With deuterons, the Na^{24} activity as a function of distance from the end of the range rises rapidly to a maximum, falls to about half the maximum, and then remains essentially constant to the highest deuteron energy. The background effects of high energy neutrons are troublesome, and no accurate method of separating them out has been found. For deuteron induced Na^{22}, the activity rises to a maximum, then stays rather constant to highest energy. With alpha-particle excitation the Na^{24} activity shows a steady drop from the maximum, while the Na^{22} curve stays rather constant to highest energy as in the deuteron case. In the case of $Al(d, \alpha p)Na^{24}$ the values can be connected with those of Clark[2] at low energies, but the spread in deuteron energy in this case makes any conclusions questionable. This paper is based on work performed under the auspices of the Atomic Energy Commission in connection with Contract W-7405-Eng 48 with the Radiation Laboratory of the University of California, Berkeley, California.

[1] R. L. Thornton and R. W. Senseman, Phys. Rev. **72**, 872 (1947).
[2] E. T. Clark, Phys. Rev. **71**, 187 (1947).

E14. 90 Mev Neutron-Proton Scattering Angular Distribution. J. HADLEY, C. LEITH, H. YORK, E. KELLY, AND C. WIEGAND, *University of California.*—The angular distribution of protons in neutron-proton scattering has been measured for angles between 5° and 55° from the direction of the incident neutron beam. The average neutron energy for these measurements was 90 Mev produced by the stripping of 190 Mev deuterons in a $\frac{1}{2}$-inch Be target in the 184-inch frequency modulated cyclotron. Thin paraffin

scatterers of known carbon and hydrogen content were used; the number of protons originating in neutron-carbon reactions was determined by using pure carbon scatterers. The scattered protons were detected in a telescope of four proportional counters used in coincidence and set at a constant distance from the scatterer but at a variable angle with the neutron beam. Between the scatterers and counters were placed copper absorbers whose thickness varied with the angle from the beam, so that only protons scattered by neutrons with energies greater than 66 Mev were counted. It was found that in the center of mass system the ratio of proton intensity per unit solid angle for perpendicular compared to forward scattering is 0.3. This forward proton peak is expected on the basis of exchange scattering. This paper is based on work done at the Radiation Laboratory of the University of California under Contract W-7405-Eng-48 with the United States Atomic Energy Commission.

SUPPLEMENTARY PROGRAMME

SP1. Near Infra-Red Dichroism Involving Hydrogen Bonds. LEONARD GLATT, *University of California.* (Introduced by Joseph W. Elli.)—A striking example of dichroism has been found in (010) cleavage sections of β-succinic acid. Very intense absorption, appearing only in E-vector components parallel to the crystallographic c-axis, caused complete opacity in the broad region from roughly 1.87μ to beyond 2.7μ, the limit of our spectrograph. This uni-directional absorption is ascribable to the intramolecular (O—H···O) hydrogen bonds which x-ray evidence has placed parallel to the c axis. The reasonable inference made by x-ray investigators that the H-atoms lie on the line connecting the O-atoms of neighboring molecules is thus confirmed. An anomalous ratio of overtone (and combination) to fundamental mode intensities for the hydrogen bond absorption is indicated by a contrast of our findings with those recently reported for the fundamental vibration region by D. A. Crooks. Adipic acid showed results similar to, but not so marked as, those of succinic acid.

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